VOLUME XXVI NUMBER 4 WHOLE NUMBER 213

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

J. S. PLASKETT
Director of the Dominion Astrophysical Observatory, Victoria, B.C.

J. PATTERSON
Director of the Meteorological Service of Canada, Toronto

R. MELDRUM STEWART
Director of the Dominion Observatory, Ottawa

PUBLISHED MONTHLY
(Ten numbers per year)

April, 1932

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXVI, No. 4 APRIL, 1932 WHOLE No. 213

Articles PAGE

Distant Universes, with Plate III - - - - - *C. S. Beals* 145
The Projection of Circles on a Mercator Map - - *S. Gold* 161
The Brighter Pleiades - - - - - - *W. H. Pickering* 171
Time (Poem) - - - - - - - *Alex. H. Sutherland* 174
Definition - - - - - - - - *G. H. Woodhouse* 175

News and Comments

Notes from the Dominion Astrophysical Observatory - *W. E. H.* 178

Notes and Queries

Doings at Mount Wilson—Ritchey's Photographic Telescope—Infra-red Photographic Plates - - - - - *C. A. C.* 180

Meetings of the Society

At London—At Toronto—At Ottawa—At Vancouver—At Montreal 183

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article attached to a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$5 50	$ 9 50	$10 00	$13 00	$10 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Business correspondence, remittances, etc., should be addresed to J. H. Horning, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

FOR SALE—5-inch refractor by Ross of London; first quality; equatorially mounted with clock and circles; 6 eyepieces, sun-glass, etc. Price, $475. HAROLD BROWN, 2108 Danforth Ave., Toronto.

PLATE III

THE GREAT NEBULA IN ANDROMEDA

The bright round object directly above the centre of the large one, and also the elliptical body to the left and below are also nebulae.

(From a photograph by Ritchey with the 24-inch reflector at the Yerkes Observatory.)

Journal of the Royal Astronomical Society of Canada, 1932.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XXVI, No. 4 APRIL, 1932 WHOLE No. 213

DISTANT UNIVERSES*

By C. S. BEALS

(With one plate)

INTRODUCTION

THE subject of our discussion this evening, "Distant Universes," may perhaps require some explanation. The dictionary definition of the word "universe" as "the aggregate of all existing things" implies an all inclusive term that could scarcely be used correctly in the plural. We shall indeed have occasion to use the term this evening in its wider significance. Current usage, however, seems to justify occasionally using the word "universe" in a more restricted sense to describe some entity that is complete in itself and which has sufficient extension and complexity to suggest the larger whole. For example, the aggregation of stars making up our own Milky Way system is sometimes referred to as our sidereal universe. Students of astronomy will also be familiar with the term Island Universe to describe a spiral nebula. The spiral nebulae are, in fact, the distant universes that we are to discuss this evening. The magnificent and awe-inspiring nature of these beautiful objects seems to justify referring to them in this way, and it is hoped that no confusion may arise through using the term "universe" in a double sense.

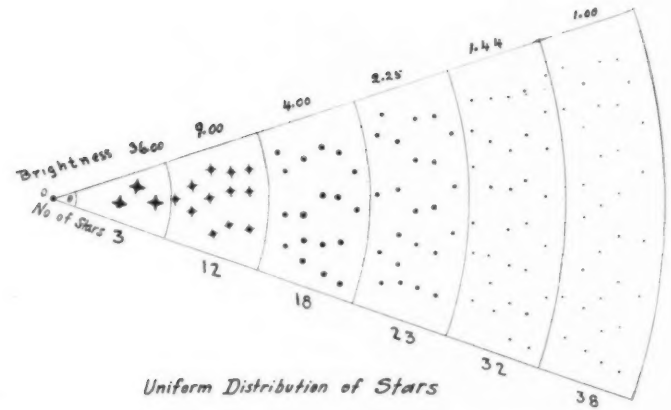
**An address given before the Victoria Centre, R.A.S.C., Nov. 24, 1931.*

Our Own Galactic System

In our talk this evening we propose to explore the depths of space as far as the most powerful instruments have been able to penetrate. In doing so we are likely to revise any previously held ideas as to what constitutes a distant object. As a beginning I wish to make some remarks about the stars in the immediate neighbourhood of our sun. As you have no doubt already guessed, the term "immediate neighbourhood" must be given a very broad interpretation in anticipation of our new ideas on the subject of distance.

It is obvious to anyone who takes even a superficial glance at the heavens with the unaided eye that we are in the midst of a vast concourse of stars. And yet the stars visible to the unaided eye number only a few thousands. If a telescope of even moderate power be employed the number is greatly increased, and it is estimated that the number of stars that can be photographed with our greatest telescopes are reckoned by thousands of millions. These stars all appear to be situated on the surface of a huge sphere, but we know that actually they are situated at varying distances from us. The question thus naturally arises: how are the great majority of stars distributed in space? Do they extend to indefinite distances from us or has our sidereal universe definite limits?

It has occurred to me that an astronomer who attempts to find an answer to this question is in somewhat the same position as one of our remote arboreal ancestors who was born in the middle of a forest of tall trees. For him the forest constitutes a universe and as far as the eye can see there is nothing but trees. Let us suppose, for the sake of illustration, that our ancestor is limited in his movements to a single tall tree, and let us suppose also that the dawning of intelligence in his brain has led him to experience curiosity concerning the extent of the forest. His best procedure would appear to be to ascend to the top of the tree and survey the landscape about him to see whether the trees showed any evidence of thinning out in distance. If the forest is not too large, say not more than twenty miles across, he may be able to observe such a thinning out, and he will then, no doubt, descend



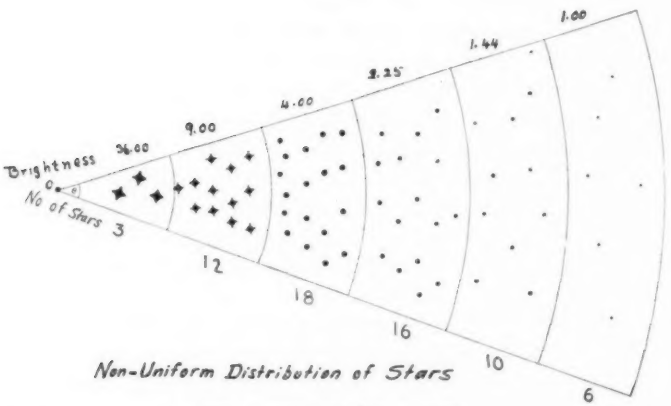


Fig. 1, above, and Fig. 2, below.

to the lower branches and inform the less scientific members of his tribe that the universe is not infinite in extent but has definite limits and that there is some evidence of other universes in the distance.

The astronomer pursues a course that is somewhat similar in principle. He also tries to observe a thinning out in the distance, but his methods are less simple. The procedure he follows is to get a powerful telescope and start counting stars of different magnitudes. He does this photographically and estimates the brightness of the stars by the impression which they make on a photographic plate. He knows that the apparent brightness of a star varies inversely as the square of its distance from him. If a certain small area of the sky be then selected and photographed it should be possible to tell by estimates of brightness the approximate distances of all the stars on a plate. The nearby stars should be bright while the more distant ones should be fainter. Since for each successive unit of distance the same area on the plate corresponds to a larger volume of space, the more distant, fainter stars should be much more numerous than the nearer, brighter ones. If the stars were uniformly distributed in space and extended to indefinite distances from us, then the number should increase indefinitely as fainter and fainter stars were considered. Such a case is illustrated in Fig. 1, in which an approximately uniform distribution of stars is represented. The observer is at 0 and he is examining an area of the sky corresponding to an angle θ. The numbers of stars in successive compartments represent the numbers of brighter and fainter stars he should see on his plate. The opposite case, where the stars thin out at considerable distances from the observer, is shown in Fig. 2. Here again the numbers of stars in different compartments illustrate the relative numbers of bright and faint stars which should be observed. Fig. 2 represents an arbitrary distribution to illustrate the method. Actual star counts, however, show that at great distances the stars do thin out in a manner somewhat similar to that shown in our diagram. The rate of thinning out, as might be expected, depends on whether the counts are made in the plane of the Milky Way or at right angles to it. It should be noted that this method assumes that all stars

are of the same brightness,—which we know not to be the case. However, if large numbers of stars are considered, the assumption is valid statistically, providing the average brightness of the stars is uniform for different regions of space.

It appears then that the stars do not extend to indefinite distances from us, but thin out in the distance just as trees on the edge of a forest. In other words, our sidereal universe has more or less definite limits and constitutes an island of space whose isolation may aptly be compared to that of an island in the ocean.

Without going further into the methods used by astronomers in studying our galactic system, we may now briefly summarize some of the main facts concerning it. The form of the galaxy is believed to be roughly that of a flat disc, or more correctly a lens or thin watch. It is believed to be in a state of rotation, and we may get some idea of this rotation by picturing an immense wheel slowly turning on its axis and at the same time moving forward through space.

The diameter of the galactic system has been estimated at 240,000 light years, while its thickness has been placed at about 20,000 light years. The nearest star to the sun is some six light years away, and this probably gives a fair idea of the average distances apart of the stars. The brightness of the Milky Way is due to the great star depth in the line of sight as here we are looking out toward the edge of the disc. The plane of the Milky Way is believed to contain a considerable amount of obscuring matter, and the effect of this obscuring matter in limiting our view of outside objects will be referred to again in a later part of our talk.

We have already spoken of likening the galaxy to an immense wheel to suggest the idea of its rotation. A more correct idea of the nature of the actual rotation itself may be gained by comparing it to the vortical motion of the water flowing out of a hand basin. There are other terrestrial analogies which may be used to illustrate other properties. The galaxy might be compared, for example, to a great city surrounded by uninhabited country, the wider spacing of the houses in the suburbs

corresponding to the thinning out of the stars as the limits of the galaxy are approached. Another analogy is that of an immense flock of birds such as may be seen on the eastern Canadian tidal rivers or, better still, to a swarm of bees which moves as a unit and yet is made up of a great number of separate individuals.

Extra Galactic Systems

The terrestrial comparisons to the galaxy which we have just made suggest a self contained unit with boundaries that are more or less distinct. The next problem which arises is, what is to be found outside these boundaries? Are there, for example, other universes of stars similar to our own galaxy? The answer is that we believe that there are indeed other similar aggregations, and it is these systems which are to take up the greater part of our discussion this evening.

The best known of these outside systems and one of the most beautiful objects in the sky is the famous nebula in Andromeda which was known as a nebula as far back as the tenth century and was first examined by a telescope in 1612. This object is easily visible to the unaided eye as a hazy patch in the constellation Andromeda whose luminosity has been estimated as between the fourth and fifth magnitudes. Its beautiful spiral form and condensed nucleus are clearly shown in the numerous photographs of this object with which students of astronomy are familiar.

Photographs of the outer regions of this nebula with the 100-inch telescope at Mt. Wilson[1] showed that they are made up of swarms of faint stars which recall the rich star fields of our Milky Way. This discovery, that the arms of the great spiral could be resolved into stars, made it practically certain that it was an island universe, containing millions of stars, and similar in many respects to our own galactic system. Further evidence of a convincing sort of the family relationship existing between the Andromeda spiral and our own galaxy is found in observations of the spectra and variability of individual stars, which have been shown to be identical in nature with stars of our own system. As far as can be ascertained

[1] Hubble, Mt.W. Cont. 376.

the Andromeda nebula is only about a tenth the size of our own system. There are reasons for believing, however, that the spiral form is common to both, and many astronomers believe that if our galaxy could be seen from a sufficiently distant point in outside space, it would present an appearance similar to that of the Andromeda nebula.

In addition to the Andromeda spiral there are innumerable other nebulae that can be observed outside our galactic system. The majority of them appear to be of the spiral form, but other forms occur which are designated respectively as globular, elliptical, lenticular and irregular.

The distribution of these objects in the sky has been extensively studied both at Mt. Wilson[2] and at Harvard[3], and two very important features have been brought to light. The first is that the nebulae are found to be approximately uniformly distributed over the entire sky with the exception of a narrow zone extending a few degrees on either side of the plane of the Milky Way. Thus, if we go back to our illustration in which the galaxy was compared to an immense slowly revolving wheel, it is apparent that we can see nebulae in every direction except toward the rim of the wheel. If an actual wheel were being considered, we would at once come to the conclusion that the rim was obscuring the view. The appearance of spirals when seen edge on, where a ring of dark obscuring matter is plainly visible on the outer edge, suggests that this is in fact the true explanation and that the density of matter in the galactic plane prevents us from seeing out in that direction. This reasonable explanation of the fact that the spiral nebulae avoid the galactic plane is the generally accepted one and the conclusion follows from the observations that the space surrounding our galaxy is filled with spiral nebulae uniformly distributed and extending as far as the most powerful telescope can penetrate.

The second interesting fact concerning the distribution of the nebulae is that, while the great majority of them are uniformly distributed over the sky, they show some tendency to occur in

[2]Hubble, Mt.W. Cont. 324, 427.
[3]Shapley, H.B. 865, 866, 868,

clusters containing from a few hundred to a few thousand nebulae each. This tendency to appear in groups or clusters is of very great assistance to the astronomer who wishes to gain an idea of their distance. The reason for this is that there are certain statistical methods of finding distance, which, when applied to individual nebulae, may lead to such large errors as to be meaningless. On the other hand, the same methods applied to a group of nebulae all of which are at approximately the same distance, will lead to a reliable result. Such methods of finding the distances of nebulae will be discussed in a later paragraph.

Before leaving the subject of the distribution of the nebulae we may record the interesting fact that the nebulae in clusters are mostly of the globular or elliptical type with some spirals, while the nebulae which do not appear in clusters (and which make up by far the greatest number) are predominantly of the spiral form.

Including the Andromeda spiral, there are in all ten extra galactic nebulae in which individual stars can be observed. These include the Magellanic Clouds, conspicuous naked eye objects in the southern hemisphere, a number of spirals, one globular nebula and one of irregular form. The distances of these objects can be determined by observing the apparent brightness of individual stars whose absolute luminosities are known either from the character of their variability or their spectra.

For the purpose of deriving distances, main reliance is placed in the cepheid variables among which a definite relation between period and mean absolute brightness seems to be reasonably well established. We know, for example, from a study of cepheids in our own galactic system and in the Magellanic Clouds that a variable with a period of light variation of five days will have, on the average, an absolute magnitude of -1.4. If the period is two days the absolute magnitude will be -0.9 and so on for any period between six hours and forty days. From this it becomes apparent that if cepheid variables can be observed in a distant object like the Andromeda nebula and the periods of their light variation determined, then their absolute magnitudes may be found from the period-luminosity relation which has just been mentioned. Know-

ing the absolute and apparent magnitudes, a simple application of the inverse square law gives the distance of the nebula.

By a method similar in principle the distances of nebulae can be determined from observations of novae or temporary stars, some 83 of which have been observed in the Andromeda spiral. The character of the light variation of many of these novae has been carefully studied and has been found to be similar to that of novae in our own galactic system. It seems reasonable to assume, therefore, that the novae in the nebula have the same absolute brightness at maximum as galactic novae. The average apparent magnitude of novae in the Andromeda nebula is 16.5, while the average absolute magnitude of galactic novae has been estimated as around -6.1 magnitudes. An application of the inverse square law to these data gives results in reasonable agreement to those derived from cepheids and leaves little doubt as to the general order of distance of the nebula.

There are certain other stars, such as those of Wolf-Rayet and P Cygni type, which can be recognized as such on slitless spectrograms because of the bright lines in their spectra. Comparison of their apparent magnitudes with absolute magnitudes derived from similar galactic objects provides an additional check on the distances of the nearer spirals.

Finally, estimates of the apparent magnitudes of the brightest stars in the nebulae provide an additional useful criterion of distance, particularly for nebulae too distant and faint for other methods to apply. There are reasons for believing that there is a fairly definite upper limit to the absolute magnitudes that stars may reach. This limit from various sources of evidence has been placed at -6.0. Assuming this value to be correct for the average of the brightest stars in a nebula, an estimate of the distance can be made which should have at least statistical value.

The actual distances found for the ten extra-galactic objects to which these methods can be applied may be found in Table I.

The distances range from 95,000 light years for the Magellanic Clouds to some 2,400,000 light years for the nebula Messier 81. The great majority of nebulae are too faint and distant for individ-

TABLE I

Object	Distance (light years)
*Large Magellanic Cloud	95,000
*Small Magellanic Cloud	85,000
N. G. C. 6822	626,000
*Messier 33	770,000
*Messier 31 (Andromeda Nebula)	800,000
Messier 32	800,000
N. G. C. 205	800,000
Messier 101	1,300,000
N. G. C. 2403	2,050,000
Messier 81	2,400,000

ual stars to be distinguished and so other methods must be applied in the determination of their distances.

Mention has already been made of the fact that when the apparent brightness and the absolute brightness of a star are known, its distance may be found by a simple application of the inverse square law. This well known relation is the basis of all the methods of finding the distances of nebulae by observing individual stars in them.

It is reasonably obvious that for the fainter, more distant nebulae whose images on the plate appear almost like stellar points, the inverse square law will apply equally well as far stars. It therefore becomes possible, if the apparent brightness and the absolute brightness of a nebula are known, to determine its distance by the same method. The use of such a method is of course based on the assumption that the ten nebulae of Table I form a representative group and that the mean absolute luminosity derived from them is that of the nebulae as a whole. The value of the absolute luminosity of these ten objects as derived by Hubble and Humason[4] is -16.5 magnitudes with a spread of about 4 magnitudes. It is scarcely to be expected that with such a spread the use of this value of the absolute magnitude will give reliable results for individual nebulae. Its use should however be valid statistically and the method is, acordingly, extremely valuable for deriving the

*Naked eye objects.

[4]Mt. W. Cont. 427.

distances of clusters or groups of nebulae. Hubble and Humason have derived the distances of a number of such clusters or groups in their studies of the relation between velocity and distance among spiral nebulae. The values of both the approximate distances in light years and the velocities for the objects may be found in Table II. In this table the clusters are designated by the name of the constellations in which they are found.

TABLE II*

Cluster	Distance (light years)	Velocity km./sec.
Virgo	5,900,000	890
Pegasus	23,600,000	3,800
Pisces	23,000,000	4,630
Cancer	29,000,000	4,800
Perseus	36,000,000	5,200
Coma	45,000,000	7,500
Ursa Major	71,700,000	11,800
Leo	104,000,000	19,600

From this table we see that investigations of the spiral nebulae have extended our knowledge of space to a distance of some 100,000,000 light years or about 400 times the diameter of our own galaxy. The distances represented in this table represent nearly the limit of the distances that can be efficiently explored with existing equipment. No one supposes, however, that the limits of space itself have been approached. It seems probable indeed that the distances that can be reached by our most powerful telescopes are only an insignificant part of the universe as a whole. The observations tell us that the nebulae extend in approximately uniform distribution to a distance of at least 100,000,000 light years, and there seems no reason to doubt that they extend to many times this distance beyond.

Velocities of the Spirals and their Explanation

Practically the only method of determining the velocity in the line of sight of celestial objects is by observing the Doppler shift

*Tables I and II are due to Hubble and Humason, Mt. W. Cont. 427.

of the lines in their spectra. This method involves the assumption that a displacement of the lines shared by all the lines in a spectrum and proportional to the wave length of each line is due to the radial velocity of the body emitting the spectrum. Accordingly, almost without exception when the lines in a stellar or nebular spectrum exhibit a shift in wave length, this shift is interpreted as due to velocity. The velocities of several thousand stars have been observed in this way, and the same method has been applied to the extra-galactic nebulae by Slipher[5] at Lowell and by Hubble and Humason[6] at Mt. Wilson.

As compared with the ordinary run of stellar velocities the velocities of the spiral nebulae are remarkable, first for their large values and, secondly, for the fact that the great majority of them are of positive sign indicating that the nebulae are receding from us. The comparatively few negative velocities known have recently been accounted for as due to the velocity of the solar system which shares the rotational velocity of our galaxy. We may then say that, relative to our galactic system considered as a unit, the spirals all show velocities of recession.

These velocities become even more remarkable when considered in their relation to the distances of clusters as given in Table II. This table shows that while all the nebulae are running away from us, the more distant they are the faster they are running; and if a graph be plotted with the two co-ordinates as velocity and distance respectively, it will be found to be a straight line, showing that the velocities of the nebulae are directly proportional to their distances from us.

The discovery of this remarkable relationship between velocity and distance among the extra galactic nebulae has caused a considerable stir in the scientific world, and a number of the world's most distinguished scientists have been engaged in the task of trying to explain the phenomenon on the basis of physical theory. Up to the present three different points of view seem to have developed.

---

[5]Slipher, Pub. A.S.P., 28, 33, 1916; Lowell Circular, Jan. 17, 1931.
[6]Humason, Mt. Wilson Cont. 426, Ap. J., vol. 74, p. 5, 1931.

Those who adopt the first point of view are disinclined to believe that the red shift of spectral lines in distant nebulae are due to actual velocity. They suggest that some hitherto unexplained physical cause, other than the Doppler effect, may be producing the shifts observed. Zwicky[7], for example, suggests that the gravitational interaction of light with matter in its passage through inter-galactic space is perhaps responsible.

The second point of view is that of those who believe that the velocity interpretation of the red shift is correct and that the relation between velocity and distance may be explained on the basis of the theory of general relativity. Those who adopt this view include some of the most distinguished present day exponents of the theory of relativity, such as de Sitter, Eddington, Tolman, and Lemaitre.

There are others who adopt a third view and who believe that the velocity interpretation is correct but who discount explanations of the phenomenon based on the theory of relativity. Among these is H. D. Curtis[8] who has developed an alternative theory which has not yet appeared in print.

The greatest weight of scientific opinion appears to be on the side of the relativity explanation, and in conclusion I will endeavour to outline briefly some of the developments which have taken place in this field.

In 1917 W. de Sitter, as a result of the studies of relativity, brought forward his famous prediction that if the velocities of distant objects could be observed from the earth they would be found to exhibit large velocities of recession. In simpler terms his prediction meant that the universe was expanding and that all distant objects should be running away from us.

At the time the prediction was made, only three velocities of spirals were known. Since then, as we have seen, many velocities of these objects have been measured and they show, almost without

[7]Zwicky, Proc. Nat. Acad. Sci. vol. 15, p. 773, 1929.

[8]Dr. Curtis put forward some of his ideas in a seminar talk at the D.A.O. They are to appear in the article on nebulae in the "Handbuch der Astrophysik."

exception, that the spirals are receding from us. This would appear to suggest a verification of de Sitter's theory. There are, however, grave difficutlies in the way of immediately accepting this view since the theoretical world of de Sitter, on which his prediction was based, is so different from what our real world appears to be. He pictured a universe practically empty of matter. And while a limited number of spiral nebulae thinly distributed in such a universe would presumably not seriously alter its properties, it is hard to reconcile a world supposed to be empty of matter with the millions and millions of these bodies which are known to exist in the limited regions of space so far explored. The important point of de Sitter's theory is that it establishes the existence of a tendency of material bodies to scatter, as a necessary consequence of Einstein's theory of gravitation. This tendency, referred to by Eddington as the cosmical repulsion, does not appear only in a "de Sitter world" but a similar "cosmical term" must be taken into account in other hypothetical distributions of matter.

Opposed to the so-called de Sitter universe is the Einstein universe. According to Einstein's theory the existence of matter anywhere in the universe implies a curvature of space. In speaking of an Einstein world in connection with astronomical data we picture a uniform distribution of matter, gas or spiral nebulae as the case may be. Einstein's theory predicts that if such a uniform distribution of matter be sufficiently dense and if it possesses sufficient extension, then the curvature of space would be so great that it would close up entirely, forming a sphere of finite radius. In such a universe the gravitational attraction would exactly balance the tendency of the spiral nebulae to scatter and the condition would be a static one.

While the uniform distribution of matter in an Einstein world rather suggests our own universe with its observed distribution of spiral nebulae, the fact that the nebulae are all receding from us is not in agreement with the idea of a static universe such as Einstein's. The difficulty of accepting a de Sitter universe has already been stated. It would appear, then, that something between the two would be likely to fit the facts better than either.

What may be a way of escape from the various difficulties has been provided by a brilliant investigation of the Abbé Lemaitre of Belgium, who worked out a series of solutions representing a universe intermediate between that of Einstein and de Sitter. Eddington has pointed out that it can be proved from Lemaitre's formulae that Einstein's world is unstable and that, according to Einstein's laws of gravitation, the universe must ultimately either expand or contract. According to this view we may picture the original state of the universe as a uniform distribution of matter in unstable equilibrium which sooner or later is bound to be upset. The question which then arises is this: If some disturbance of a sort likely to occur upsets this equilibrium, will the universe begin to expand or contract? It was thought for a while that a satisfactory answer had been found and that the expansion observed could have been predicted as a result of the condensation of the primeval gas of the universe into spiral nebulae and stars. It is now recognized that the reasoning from which this result was derived is not valid[9] and so the search for a solution must begin anew.

In a popular discussion like the present one, we may well leave the question as to what started the expansion of the universe for the mathematical physicists to settle. If, however, we are willing to accept the expansion and its explanation as real, there are certain important consequences which follow and which should prove of considerable interest to us. According to the theories of Lemaitre as developed by Eddington[10] the universe is expanding at a rate which is constantly increasing and ultimately the nebulae must be separating at a speed which exceeds the velocity of light. They will then cease to have any casual connection with one another and will drop below our horizon forever.

The all important deduction which has recently been given prominence in scientific discussion is that the time necesary for this to happen (of the order of 10^{10} years) is small relative to what has been considered to be the average age of the stars. If, as

[9]McVittie and McCrea, Observatory, vol. 54, p. 267, 1931.
[10]Eddington, M. N. XCI, p. 413, 1931.

Eddington appears to consider necessary, we picture the birth of the stars as taking place after the expansion of the universe has begun, then the magnitude of the time scale which can be permitted is much too small to fit in with current theories of stellar evolution. Even the time available for the evolution of life on the earth becomes uncomfortably limited, and not only astronomers but geologists and biologists as well are faced with the possibility of having to discard some of their most cherished theories.

De Sitter, holding a somewhat opposite view to that of Eddington, appears to think that the evolution of the stars and nebulae on the one hand and the expansion of the universe on the other must be regarded as separate phenomena, taking place side by side but without any apparent connection between them. He suggests that the universe might have remained stationary at, or near, its minimum size for an indefinitely long period of time before beginning to expand. Or that it might have contracted for an indefinitely long time, passed through a minimum and then started to expand. In either case the evolution of the stars could have been going on for an indefinite period before the expansion started.

Finally, it should be emphasized that in recording these suggested explanations of the observed velocities of the nebulae we do so without implying that they are to be regarded in any sense as final. The subject is really in its infancy and the problems presented are among the most difficult and puzzling in the whole field of astrophysics. The brilliant attempts that have been made to explain an expanding universe on the basis of the theory of relativity must necessarily engage our keenest interest. It would appear, however, that it is safest to suspend judgment on the results for the present, and one may hazard a guess that it will be many years before the matter is finally removed from the field of controversy.

THE PROJECTION OF CIRCLES ON A MERCATOR MAP

By S. Gold

IN this article it is proposed to arrive at the equations of small circles with a given centre, and of great circles passing through a given point, when the sphere on which they lie is projected on a plane by the Mercator method. A short account of the theory of the Mercator map projection will first be given.

Mathematically this map projection is a conformal cylindrical one. The parallels and meridians are projected in a certain manner on the cylinder tangent to the earth at the equator. The surface of this cylinder is then developed into a plane and the map can be constructed by aid of the network. All angles are preserved and the scale is the same in every direction at any point.

We shall consider the earth as a sphere of radius R. Let λ and ϕ denote longitude and latitude respectively.

For the intersections of the meridians at the equator, we have

$$x = R\lambda.$$

Taking this line as the x-axis, all lines perpendicular to it will be meridians. Let the central meridian be the y-axis.

An arc along a parallel of latitude equals $R\lambda \cos \phi$. Since this length must give the same value of x at all latitudes, we must divide it by $\cos \phi$. In order that the scale along a meridian be the same, for conformality, we must divide the element of length on the meridian by $\cos \phi$ also.

But the element of length along a meridian is $Rd\phi$. Hence on the map we must have

$$dy = \frac{Rd\phi}{\cos \phi}.$$

Accordingly, for a given latitude ϕ,

$$y = R\int_0^{\phi} \frac{d\phi}{\cos \phi}$$

$$= R \log \tan \left(\frac{\pi}{4} + \frac{\phi}{2}\right).$$

In drawing the map the co-ordinates x and y must be reduced to a practical scale (of the order of one millionth). The formulae of the transformation then become

$$x = a\lambda \tag{1}$$

$$y = a \log \tan\left(\frac{\pi}{4}+\frac{\phi}{2}\right) \tag{2}$$

where $a = 10^{-6}R$, say.

Now $$\tan\left(\frac{\pi}{4}+\frac{\phi}{2}\right) = \sqrt{\frac{1+\sin\phi}{1-\sin\phi}}$$

$$= \frac{\cos\phi}{1-\sin\phi}$$

$$= e^{y/a}.$$

We readily obtain that

$$\left.\begin{aligned} \sin\phi &= \tanh\frac{y}{a} \\ \cos\phi &= \operatorname{sech}\frac{y}{a} \\ \tan\phi &= \sinh\frac{y}{a} \end{aligned}\right\}. \tag{3}$$

Figure 1* is an azimuth-distance map for Ottawa on a Mercator projection. Distance circles are drawn at intervals of 10° and azimuth lines at intervals of 20°. In the following we will deduce the equations of these plane curves.

Let ϕ_0 be the latitude of the centre of a circle of radius r. There is no loss of generality by taking the meridian through the centre as the central meridian. The co-ordinates of the centre on the map will accordingly be $(0, y_0)$, where y_0 is given by (2). Further, let ϕ and λ denote the latitude and longitude of any point Y on the circumference of the circle.

Three distinct cases occur, viz., when the circle intersects the central meridian between the centre and the pole, at the pole, and

---

From Pub. Dom. Obs., Vol. VII, No. 6.

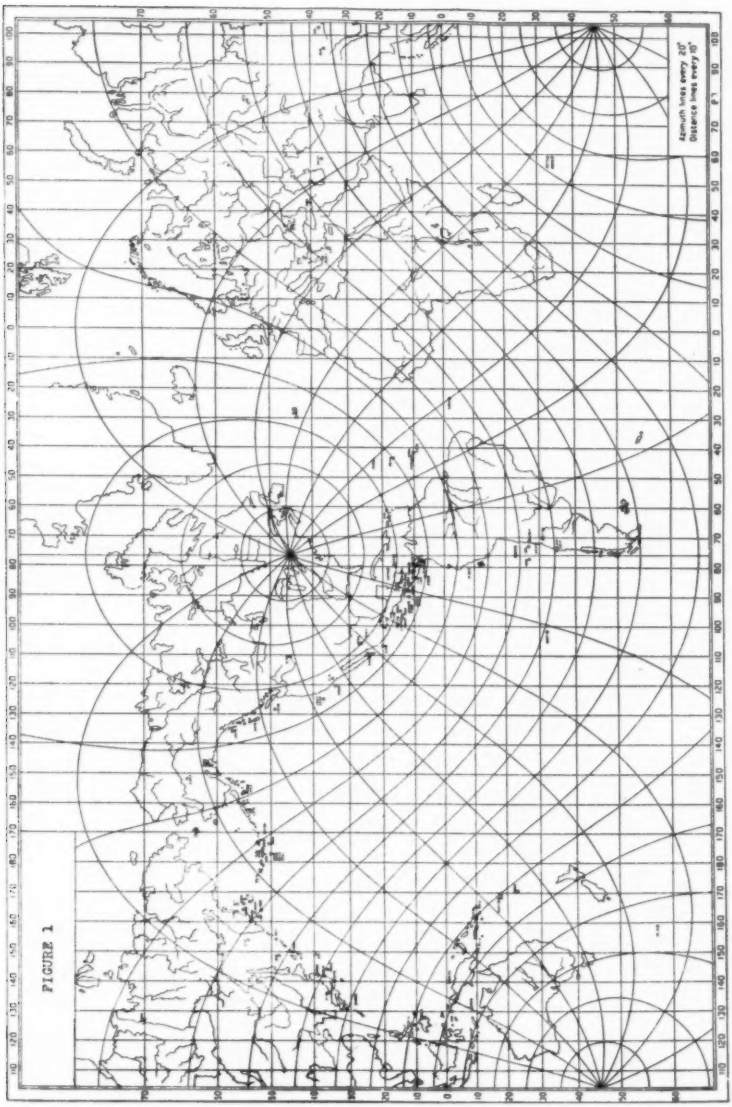

Distances and Azimuths
20° Arcs with Radii
10° Arcs with Radii

FIGURE 1

beyond the pole. These cases depend on the length of the radius compared with the co-latitude of the centre.

CASE I. $r < \frac{\pi}{2} - \phi_0$.

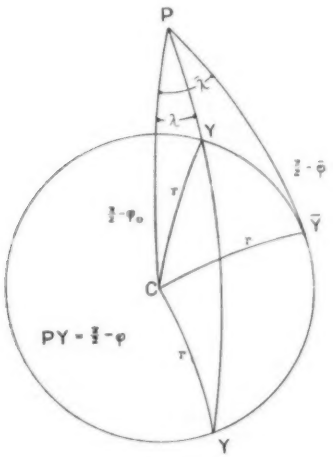


FIGURE 2

The co-ordinates of Y obey the equation

$$\cos r = \sin \phi_0 \sin \phi + \cos \phi_0 \cos \phi \cos \lambda. \tag{4}$$

Put $\cos r = A \cosh \omega$

$\sin \phi_0 = A \sinh \omega$.

Then $A = \sqrt{\cos^2 r - \sin^2 \phi_0}$

and $\tanh \omega = \dfrac{\sin \phi_0}{\cos r}$.*

Substituting in (4) and using (3), we obtain

$$A \cosh\left(\frac{y}{a} - \omega\right) = \cos \phi_0 \cos \frac{x}{a}.$$

*This transformation is possible since $\sin \phi_0 < \cos r$, so that $\tanh \omega < 1$.

Suppose the circle touches a meridian at $\bar{Y}$, $(\lambda, \bar{\phi})$. Then $P\bar{Y}C$ is a right angle.

Hence $\cos \phi_0 \sin \bar{\lambda} = \sin r$,

so that $\cos \phi_0 \cos \dfrac{\bar{x}}{a} = \sqrt{\cos^2\phi_0 - \sin^2 r} = A$.

Accordingly it follows that

$$\cosh\left(\frac{\bar{y}}{a} - \omega\right) = 1,$$

or $$\omega = \frac{\bar{y}}{a}.$$

The equation is finally

$$\cos \frac{x}{a} = \cos \frac{\bar{x}}{a} \cosh \frac{y - \bar{y}}{a} * \qquad \text{(i)}$$

where $\cos \dfrac{\bar{x}}{a} = \sqrt{1 - \sin^2 r \sec^2 \phi_0}$, and $\tanh \dfrac{\bar{y}}{a} = \sin \phi_0 \sec r$.

CASE II. $r = \dfrac{\pi}{2} - \phi_0$.

Equation (4) here becomes

$$\sin \phi_0 = \sin \phi \sin \phi_0 + \cos \phi \cos \phi_0 \cos \lambda,$$

i.e., $$\tan \phi_0 = \frac{\cos \phi}{1 - \sin \phi} \cos \lambda. \qquad (5)$$

With (1), (2), and (3) we find that the equation of the curve in this case is

$$e^{y/a} \cos \frac{x}{a} = \sinh \frac{y_0}{a} \qquad \text{(ii)}$$

where $\sinh \dfrac{y_0}{a} = \tan \phi_0$.

---

*This equation can also be written

$$\cos \frac{x}{a} = \sinh \frac{y_0}{a} \operatorname{cosech} \frac{\bar{y}}{a} \cosh \frac{y - \bar{y}}{a}.$$

Cf. Equation (iii).

CASE III. $r > \frac{\pi}{2} - \phi_0$.

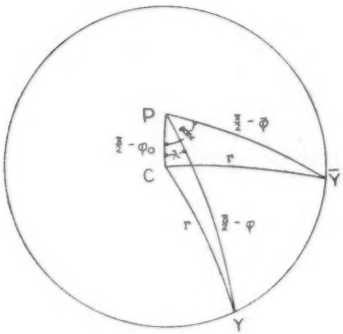


FIGURE 3

As in Case I, we have

$$\cos r = \sin \phi_0 \sin \phi + \cos \phi_0 \cos \phi \cos \lambda. \tag{4}$$

Put $\cos r = A \sinh \omega$

$\sin \phi_0 = A \cosh \omega$.

Then $A = \sqrt{\sin^2 \phi_0 - \cos^2 r}$

and $\tanh \omega = \frac{\cos r}{\sin \phi_0}$.*

Substituting in (4) we obtain

$$A \sinh\left(\omega - \frac{y}{a}\right) = \cos \phi_0 \cos \frac{x}{a}.$$

When $\lambda = \frac{x}{a} = \frac{\pi}{2}$, let $y = \bar{y}$.

Now $A \sinh\left(\omega - \frac{y}{a}\right) = 0$,

or $\omega = \frac{\bar{y}}{a}$.

*Here $\cos r < \sin \phi_0$.

Also $$A = \sin\phi_0\sqrt{1-\tanh^2\omega}$$

$$= \sin\phi_0 \operatorname{sech}\frac{y}{a}.$$

The equation is now

$$\cos\phi_0 \cos\frac{x}{a} = \sin\phi_0 \operatorname{sech}\frac{\bar{y}}{a}\sinh\frac{\bar{y}-y}{a}.$$

Finally we have

$$\cos\frac{x}{a} = \sinh\frac{y_0}{a}\operatorname{sech}\frac{\bar{y}}{a}\sinh\frac{\bar{y}-y}{a} \qquad \text{(iii)}$$

where $\sinh\frac{y_0}{a} = \tan\phi_0$, and $\tanh\frac{\bar{y}}{a} = \cos r \operatorname{cosec}\phi_0$.

There is a rather interesting property of the projected distance circles which reduces the computation in drawing them by one-half.

In Case I, each circle intersects each meridian twice. Let y_1 and y_2 be the ordinates for any given (possible) meridian.

If we put $Y = y - \bar{y}$, the values of Y for the given meridian will be Y' and $-Y'$, say.

Then $$Y' = y_1 - \bar{y}$$

$$-Y' = y_2 - \bar{y}$$

so that $$y_1 + y_2 = 2\bar{y} = K, \text{ say,}$$

where K is a constant for the circle.

In fact $$K = a\log\frac{1+\sin\phi}{1-\sin\phi}$$

$$= a\log\frac{1+\sin\phi_0\sec r}{1-\sin\phi_0\sec r}$$

$$= a\log\frac{\cos r+\sin\phi_0}{\cos r-\sin\phi_0}.$$

In Case III, each circle intersects every meridian once only. However, each circle intersects every meridian circle twice, the difference in longitude being 180°.

Let y_1 and y_2 be the ordinates for any meridian circle. By (iii) we obtain

$$\frac{\cos\lambda}{\cos(\pi+\lambda)} = \frac{\sinh\dfrac{\bar{y}-y_1}{a}}{\sinh\dfrac{\bar{y}-y_2}{a}},$$

whence $$-\sinh\frac{\bar{y}-y_1}{a} = \sinh\frac{\bar{y}-y_2}{a}.$$

Then $$y_1-\bar{y} = \bar{y}-y_2$$

so that $$y_1+y_2 = 2\bar{y} = K', \text{ say.}$$

It is easy to prove that

$$K' = a\log\frac{\sin\phi_0+\cos r}{\sin\phi_0-\cos r}.$$

In Case II, the circle intersects each meridian twice, one point being the pole, which is at infinity on the map.

In computing the distance lines on the chart, the latitudes of the points of intersection of the circles with a set of meridians are determined. With the constant for a given circle known, the work of computing can be very simply checked in Case I, while in Case III, it is necessary to find the intersections up to 90° of longitude only.

Then $$y_{180°-\lambda} = K'-y_\lambda.$$

Azimuth Lines

We proceed to find the equations of great circles passing through a given point and making a given angle with the meridian through the point, when projected on the Mercator map.

Let ϕ_0 be the latitude of the given point, C. We may take PC as the central meridian, without loss of generality. Let CY make an angle θ with PC. Draw PD perpendicular to CY and suppose it makes an angle ω with PC. Denote the latitude and longitude of Y by ϕ and λ.

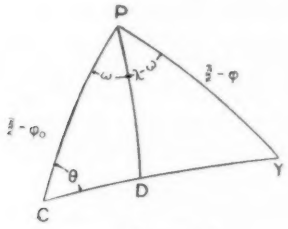


FIGURE 4

Then $$\cos\left(\frac{\pi}{2}-\phi_0\right)=\cot\,\omega\,\cot\,\theta$$

i.e. $$\cot\,\omega=\tan\,\theta\,\sin\,\phi_0.$$

Also $$\cos(\lambda-\omega)=\tan\,PD\,\cot\left(\frac{\pi}{2}-\phi\right)$$

$$=\tan\,\phi\,\cos\,\omega\,\cot\,\phi_0.$$

Therefore $$\tan\,\phi=\frac{\tan\,\phi_0\cos\,(\lambda-\omega)}{\cos\,\omega}. \qquad (6)$$

Since ω is an angle of longitude, let $x=a\omega$.

Substituting in (6) with (1), (2), and (3), the required equation is

$$\frac{\sinh\frac{y}{a}}{\sinh\frac{y_0}{a}}=\frac{\cos\frac{x-\bar{x}}{a}}{\cos\frac{\bar{x}}{a}} \qquad \text{(iv)}$$

where $\sinh\frac{y_0}{a}=\tan\,\phi_0$, and $\cot\,\frac{\bar{x}}{a}=\tan\,\theta\,\sin\,\phi_0$.

From (iv) it follows that the azimuth lines for the angles θ and $-\theta$ are symmetrical about the y-axis. Further, it is easily proved that for a given azimuth line

$$y_{180°+\lambda}=-y_\lambda.$$

Hence when drawing these lines it is necessary to make computations only for azimuth angles up to 90°.

Distance lines and azimuth lines generally form part of a detailed study of an earthquake and its effects. These lines are drawn about and through the epicentre of the earthquake.

In conclusion, the author desires to acknowledge his indebtedness to Mr. Stewart, Director of the Dominion Observatory, to whom the method of the above analysis is largely due.

Dominion Observatory,
Ottawa, November, 1931.

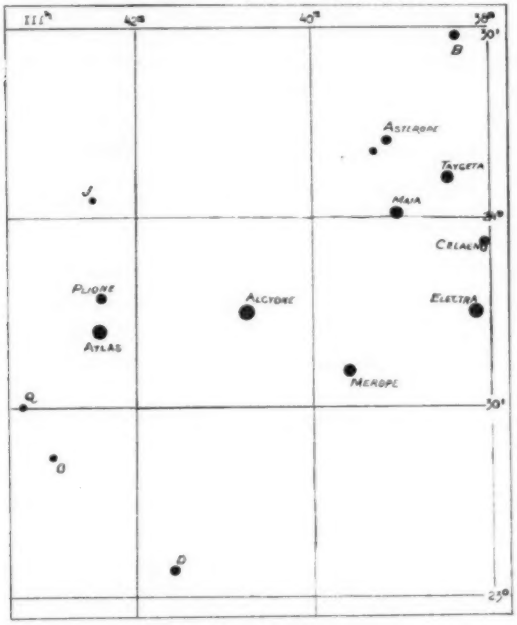
THE BRIGHTER PLEIADES

By William H. Pickering

Many a night I saw the Pleiads, rising through the mellow shade
Glitter like a swarm of fireflies tangled in a silver braid.

MANY a night as a boy and a young man, fifty and more years ago, I watched the Pleiads, and could always hold ten of them easily with the naked eye. The eleventh *D*, (see map) ! could sometimes glimpse, but it was rather difficult. Now with an opera glass I can see just as much as I could then with the naked eye. The star Celaeno, however, I now find difficult, doubtless because it is partly surrounded by the bright stars Taygeta, Maia, and Electra. When I was young I never considered it so at all. As I recall it, it was easier than either *B* or Asterope. With a low power, such as an opera glass, it is now distinctly more difficult than either of them. With my 2-inch finder, which shows the whole group in the field at once, eighteen comparisons with *B*, Asterope, and Plione give the magnitude of Celaeno as 5.57 ±0.14, or 0.14 fainter than its value in the Draper Catalogue, so it evidently has not changed much since those comparatively recent observations were made. In measuring the brightness I always move the telescope so as to have the point halfway between the two stars considered, at the centre of the field. Celaeno looks to me now a little more hazy and reddish than Plione, but this is probably some defect of my eye, though I do not see why it should be so. *D* is at present, I am convinced, a full magnitude brighter than it was fifty years ago. The spectrum of *D* differs from that of the other stars of the group in that the hydrogen lines are sometimes bright and sometimes dark. Possibly the lines in Celaeno may formerly have been bright. Ten comparisons with Celaeno, *B*, Asterope, and Plione give the brightness of *D* as 5.19 ±0.19, or 0.32 brighter than as given in the Draper Catalogue. It is now brighter than Celaeno, *B*, and Asterope, and practically equals Plione, all of which stars were easily seen fifty odd years ago. To the naked eye or with an opera glass the double Asterope appears as one. I have inserted *O*, *J*, and *Q* upon the map as the next brightest stars in the group.

They range from magnitude 6.1 to 6.7. Alcyone is of magnitude 2.96.



Map of the Pleiades.

Everybody knows the Pleiades as the seven stars, but not everybody knows which stars they are. Atlas and Plione were supposed to be the father and mother of the seven young ladies. The stars whose names appear on the right of the figure represent the young persons themselves. The story of the Lost Pleiad, it is found, was known to the aborigines throughout the world just as it was to the ancient Greeks. Eratosthenes writes of the seven-starred Pleiad, but says that one of them is invisible. Aratos also mentions the legend. The Iroquois Indians, however, changed the sex, and said they were seven little boys who were carried up to heaven, but one became homesick, and he was the dim one. The black Australians say they represent a queen and her six attendants, and that Canopus

ran away with the queen, leaving six. Some of the South Sea Islanders claim that the Pleiads were once only one star, but that the god Tane hurled Aldebaran at it, and broke it into six parts. The Dyaks and Malays considered them to be seven chickens, one of which had disappeared. The South American Indians called them the six stars. Similar stories are told in Japan and on the African Gold Coast. All of this information, and much more, will be found in Olcott's "Star Lore of all Ages" and Miss Clerke's "System of the Stars". As to which Pleiad was lost, there seems to have been much difference of opinion. Some of the Greeks said it was Electra, and others that it was Merope, but as both of these stars are now fairly bright, neither seems very likely to have been the one. Another story is that it was Asterope, which is much fainter. Still another claimant is Celaeno, who was said to have been struck by lightning.

If some old astronomer or medicine man had seen this star bright in his youth, and if in his old age it had faded ever so little, or had perhaps not even faded at all, the story might very well have spread in a non-critical age. Another suggestion may be that since *D* is actually a variable star, and is at present brighter than several of those readily visible, although considerably outside of the group, it may have furnished the world wide foundation of the story. Another suggestion that has been made is that a *nova* suddenly appeared in the cluster surrounding the brighter stars, and was so brilliant that it attracted widespread attention even among unintelligent races. When it finally faded out, the remaining six brighter stars were left. The South Sea Island story would then be the best description of the phenomenon that we have. On the other hand, perhaps there never was a lost Pleiad after all. Seven has always been considered a sacred number throughout the world, and as there were only six bright Pleiads, the story might readily have grown that one had been lost, or had faded out. This is perhaps the most likely of all.

Private Observatory,
Mandeville, Jamaica, B.W.I.
December 15, 1931.

TIME

Time only is the essence of all life.
Within its endless power, worlds flit and fade,
And shine again in light of other worlds.
The universe itself, that glittering diadem,
That crowns the mystic brow of heaven's eternal king,
Is but a dewdrop in the day of Time's unceasing sway;
Reflecting back a moment in its melting mirror
One perfect thought, one star-like ray
In heaven's majestic destiny.

The glory of all things that were or are
Falls in the lap of Time and fades,
As bubbles by a school-boy blown upon the breeze,
Or flecks of foam upon the ocean borne,
That sparkle for a moment in the morning sun,
Then sink into forgetfulness again.
And, what the life of man; his hopes and creeds,
His splendid yearnings for, (he knows not what
of other forms and fears)
His sacred aspirations for a spirit world?

Is his the shadow of the mystic clouds,
That float beneath the gaze of God above,
Catching a faint reflection of his life and light,
Then passed from out the landscape of his dream;
Or, are these torches of celestial flame,
Lighted by God himself, to glow or fade
Of their own power divine,—eternal lights?
Time only in his deep oblivion holds the key,
And in his endless eons will reveal.

But thou,—Oh man!
Who would'st prepare thy soul for immortality,
Gather from Time's unceasing store
The jewels of the moments and the hours.
Fanning the flame thou feelest in thy breast,
Make Time thy friend.
So shalt thou step from off the brink,
And fluttering in thy robes of purity,
Sail out across the vast abyss of years
On glorious wings of love and perfect trust.

ALEX. H. SUTHERLAND.

Victoria, B.C.

DEFINITION*

By G. H. Woodhouse

THIS astronomical term has a double application. The first has relation to the telescope objective; the second, and more elusive, to the state of the atmosphere at the observing station. For the purpose of this article no notice will be taken of the first, as, being a function of the objective, it allows no great variation so that, for the amateur, it presents no great field for investigation.

The second, or atmospheric definition, can, however, be easily studied by the amateur with quite moderate instrumental equipment.

Theoretically, there is no limit to instrumental definition; that is to say, we can continue increasing the apertures and focal lengths of our telescopes, and, by the use of suitable eyepieces, secure magnifications of many thousands; but here the atmosphere intervenes, completely nullifying the optician's art. True it is that the astronomer can, by carefully choosing an elevated mountain peak in a good area, somewhat rectify matters. But mountain tops are not always available or accessible, and, even there, atmospheric troubles are met with.

The cause of these troubles is that we live at the bottom of an aerial ocean, which is, comparatively speaking, rather shallow, susceptible to changes in temperature, and therefore showing many degrees of density within a small area. Physiologically, we have every reason to be glad that air is such a poor conductor of heat, for on a hot summer's day asphalt, concrete and iron surfaces absorb a great deal of heat, and hence may indicate temperatures ranging from about 100° to 200°. The air above them cannot absorb so much heat, but becomes warm by innumerable convection currents ascending through the whole, in exactly the same manner as the water in a kettle becomes warm through absorbing the heat from the bottom of the container, which is heated by a flame. The

*From *Bulletin of the Victoria Astronomical Society.*

air, unlike the water in the kettle, is not confined, and, being free to move over a large area, takes a very long time to heat up. The changing densities due to this motion are therefore the cause of the varying definition.

When an object is in the zenith the effect is not as noticeable as when the altitude is slight; moreover, it is sometimes better on different sides of the zenith; for instance, an observer may be looking at an object over heated air arising from a city, and, on turning his telescope to another object over an extensive sheet of water, get an entirely different effect. It is a fact not generally known, that a sheet of moderately still water reflects a considerable amount of heat. When the conditions are right, on a hot summer afternoon, this phenomenon may be felt on the west side of Princes Bridge over the river Yarra at Melbourne; the writer has done so frequently. The effects here described are more or less local, and a few hours after sunset they may become negligible. In a fixed observatory these conditions are frequently met with, so that a note appended to an observer's work for the night frequently reads: "Definition poor at beginning but improving towards the end of the programme." These conditions may be described as normal.

Suppose now the object to be a star; if the air is quite tranquil or homogeneous throughout, the observer sees in his field of view a disc of light surrounded by one or more rings of light, the disc appears to roll along without tremors of any kind, allowing micrometer setting to be made with ease; to such an observation the observer would append a weight of 10, the full weight; this has only happened a few times to the writer's knowledge; the more normal condition is for the star to present a certain amount of fuzziness, combined with an erratic movement across the field of view, calling for great care in making the micrometer setting, such an observation receiving a weight of 5 du to 7 du, the figures indicating the difficulty of setting, and the letters the appearance of the object, "d" meaning diffused and "u" unsteady.

Some years ago the writer, for quite another purpose, was anxious to find out the weights given to observations at observatories at various parts of the world and arrived at a mean result of 6.

At the Melbourne Observatory there is a certain type of definition which compels the observer to weight his observations as low as 2 to 5 du, so that the images are slightly larger than normal, and have much the appearance of being viewed through running water. When such are the observing conditions the observer can safely say that the following day will be cloudy with rain probable; undoubtedly, therefore, such definition is associated with some approaching meterological change. Somewhere about 1890 an American amateur astronomer, using the sun and moon for his purpose, was able to predict the direction of the wind for the following day, by carefully noting the progress of the ripples, which can be seen round these luminaries, and carefully charting them.

This phase of astronomy has been overlooked for a long time; no one seems to have bothered much to seek for the conditions that make atmospheric definition so variable. Here then is a chance for the amateur with very moderate equipment to render real service by correlating the following meteorological conditions with the preceding definition.

Melbourne, Australia.

NEWS AND COMMENTS

NOTES FROM THE DOMINION ASTROPHYSICAL OBSERVATORY

THESE notes cover the past six months as your scribe has again been dilatory. The weather being usually an important topic to astronomers, the observing statistics will first be given. With the exception of November the observing weather was somewhat below the average.

1931			12-year average	
Month	Nights	Hours	Nights	Hours
September	14	83	20	150
October	15	109	17	126
November	17	122	12	88
December	7	44	10	59
1932			13-year average	
January	9	49	10	70
February	12	76	14	93

While one spectrum plate is considered no more important than another, requiring equal observing time, peculiar interest is always attached to those that happen to bear the number of the even thousand. The 20,000th plate was secured on the night of September 23rd, and at the end of February the serial number was 20,330.

In keeping with the economic depression, the number of tourists and visitors has fallen off. During 1931 the total number visiting the institution was approximately 24,840, as against 33,318 of the year preceding and 39,027 for 1929.

Among some of the outstanding scientists who visited us was Professor (Emeritus) Henley of Yale, formerly electrician to Edison, who had recently been in attendance at six International Congresses and who returned from Europe in company with

Mitchell, Schlesinger, and de Sitter. Professor H. D. Curtis, Director of the University of Michigan Observatory at Ann Arbor, also spent a few days with us and favoured us with a talk at one of our Seminar meetings. His visit to the western observatories, which he made by automobile, was with a view of collecting information helpful in the design of the new reflector for Ann Arbor. Dr. H. Spencer Jones of South Africa was also a visitor for a couple of days and his talk on Nova Pictoris at a Seminar meeting as well as his informal discussions with members of the staff were much enjoyed.

Whether it was because the government feared that some of the members of our staff who have a reputation for speeding might come to grief on the narrow road leading up from the main road to the Observatory, or whether it was simply the desire to create work for the unemployed, the fact is that we are having the road up greatly widened and improved. Some fifty men during the past few months have been engaged on this work, for which $20,000 was appropriated. Occasionally a heavy blast when one is measuring a spectrum plate will give the impression you are dealing with a double-liner. However, the work is nearing completion, and when finished may prove even more tempting to speedsters.

Congratulations are due the Director, Dr. J. S. Plaskett, who has been awarded the Bruce medal for "distinguished services to Astronomy." He will receive the medal in April when he will deliver an address to the A.S.P. He has also been awarded the Flavelle medal, awarded annually by the Royal Society of Canada, which will be received at the forthcoming meeting in May. At that time also McGill University is conferring the degree of LL.D. upon him.

W. E. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Doings at Mount Wilson

The report of the director of the Mount Wilson Observatory for the year 1930-31 has just been received. It contains fifty closely-printed pages and gives a succinct outline of the progress made in the numerous and varied researches being carried on there. To summarize it is impossible since the report is made up of brief accounts of the investigations completed or going forward. The following extracts will be of interest to the general public as well as to the astronomer.

One of the most interesting results of the year is the further confirmation of the fundamental relationship between distance and amount of red-shift found by Dr. Hubble and Mr. Humason in the spectra of the extra-galactic nebulae. The most recent observation of this character is of a faint nebula in a cluster in the constellation of Leo, the distance of which is estimated by Hubble at 105 million light-years. The red-shift on a spectrogram obtained by Humason amounts to about 300 angstroms, which would correspond to a radial velocity of +19,700 km./sec., by far the largest displacement ever observed in the spectrum of any object. (A still greater displacement, corresponding to a velocity of about 23,000 km./sec., has since been obtained—*Editor.*) The "velocity"-distance relationship has now been established from observations of over 50 nebulae, 31 of which occur in clusters. Whether these huge red-shifts are to be interpreted directly as motions of recession, which would imply a rapidly expanding universe, is as yet uncertain, although no other adequate explanation has as yet been offered. In any event this relationship between distance and red-shift must remain an observational result of profound significance in its bearing on the nature and development of the stellar universe.

. . . . . .

Solar activity, as measured by the number of sun-spot groups, has decreased, the average daily number during 1930 being 3.8, as compared with 6.0 in 1929. The phase of the spot-cycle at present is about half-way between maximum and minimum. The polarities of 221 groups have been observed, 80 per cent. being regular, 6 per cent. irregular, and 14 per cent. unclassified. Two small bipolar groups in high latitudes had polarities opposite to those

of the present cycle, but can not be regarded with certainty as forerunners of the next cycle.

. . . . . .

The most probable mass of Pluto, as determined by Nicholson and Mayall from the perturbations of Neptune, is about two-thirds that of the earth. Visual observations of Pluto with the 100-inch reflector have so far shown no evidence of a measurable disc. An attempt to derive a mass for the satellite of Neptune has been made by van Maanen, Nicholson and Willis. From measurements made on 14 nights when the planet was nearly stationary, the most probable value is between 0.04 and 0.1 the mass of the earth.

. . . . . .

The adjustment and operation of the 50-foot interferometer have been continued by Pease, who has observed fringes with mirror-separations up to 44 feet. Measurements of Alpha Orionis give an angular diameter of about 0″.040 and of Beta Andromeda, 0″.016.

. . . . . .

Measurements of the velocity of light through the one-mile pipe line, with the air-pressure reduced to about 2 mm. over the path traversed by the light, have been continued by Pease and Pearson since Dr. Michelson's death early in May (1931). The base-line was measured with a remarkable degree of precision by Commander Garner of the U.S. Coast and Geodetic Survey. Thus far five sets of observations have been made, each consisting of 60 or more groups of 20 micrometer readings each. The first two sets are of low weight because of a slight drift in the image, and one of these gives a systematically low value. The other four sets are, however, closely accordant. . . . The first measurements were made on February 19, 1931, and were continued intermittently until July. Five series of observations have been completed, all with the use of the 32-sided rotating mirror figured by Mr. Pearson. Two of these were over an optical path of approximately 10 miles and the other three over a path of 8 miles. The length of the base-line is 5230.76509 feet.

. . . . . .

Observing conditions during the year were well above the normal of those recorded during the last 19 years. Solar observations were made on 302 days and stellar observations on 298 nights. The 60-inch reflector was in use 2454 hours as compared with an average of 2260 hours, or during nearly 70 per cent. of the total estimated hours of darkness.

Public use of the 60-inch telescope for visual observations has been continued on Friday evenings throughout the year, and there has been a large increase in the number of visitors to Mount Wilson on these evenings. More than 8200 persons used the instrument during the year, among whom were many high school and college students. Mr. W. P. Hoge has given the public lectures on these occasions and has supervised the observations with the telescope.

Ritchey's Photographic Telescope

In *Science News Letter* it is reported that great progress is being made in the construction of the new 40-inch photographic telescope which Prof. G. W. Ritchey is making for the U.S. Naval Observatory. The discs for the 40-inch and 16-inch discs, cast from a heat-resistant glass similar to pyrex at the Saint Gobain works in Paris, have been received. They will be ground and polished in the workshops of the Observatory, and this will require fifteen months. As is well known, Professor Ritchey was responsible for the design of the 60-inch and 100-inch telescopes at the Mount Wilson as well as for their optical parts, and photographs taken by him with the 60-inch have never been excelled. In his opinion the 60-inch is twice as efficient photographically as the 100-inch and he declares his new instrument will be ten times as efficient as the 60-inch.

The heavier outside parts of the mounting, which weigh about ten tons, have been completed in a shop near Philadelphia, and the lighter parts will be constructed at Washington. Full details of the construction and performance of this instrument will be awaited with great interest.

Infra-red Photographic Plates

Dr. C. E. Kenneth Mees, director of research by the Eastman Kodak Co., has supplied another valuable aid for physical research. By using a new dye, discovered in his laboratories and named zenocyanine, as a bath for photographic plates, they become sensitive to radiation of great wave-length. By employing these plates at the U.S. Bureau of Standards there have been discovered in the spectra of the chemical elements many new lines with wave-lengths between 9,000 and 11,200 angstroms. The dye must be synthesized just before use and the plates kept in cold storage or they will be fogged from radiation at ordinary room temperatures. These experiments recall those made by Abney, the great English pioneer in photography, who died in 1910. As early as 1880 he produced photographs by wave-lengths as great as 22,000 angstroms.

C. A. C.

MEETINGS OF THE SOCIETY

AT LONDON

January 8, 1932.—A regular meeting was held at 8 p.m. in the London Life Building. There were 47 people present, with four elections to membership in the Society, viz:

Miss Lila Scott, 847 Maitland St., London.
Mrs. J. E. McGuffin, 27 Thornton Ave., London.
Mr. E. M. S. Dale, 297 Hyman St., London.
Mr. J. Higgins, 324 Wolfe St., London.

Mr. T. C. Benson conducted a constellation study—the constellations Aries, Taurus, Auriga, and Orion being discussed by means of charts. President McKone next introduced the speaker of the evening, Major E. H. Anundson, who presented a paper on "Newer Developments in the Calendar Reform".

The speaker briefly reviewed facts which had been brought out in his April (1931) lecture on the calendar. These covered the modern history of the movement for reform, ancient history of calendars, and difficulties with which calendar makers have to contend. He showed that it was necessary to fit an artificially inflexible day into an astronomically inflexible year and pointed out that there is no common denominator for time as divided by the daily revolution of the earth, by the moon as it circles around us, or by our yearly voyage around the sun. He also reviewed those idiosyncrasies of the present calendar which have come down to us from the days of the Caesars. For example, the year was begun on January 1 instead of with the winter solstice simply because the Roman people had been accustomed to a lunar calendar. Also the name of one month was changed to July in order to do honour to Julius Caesar. A few years later the name of another month was changed to August in order that honour might be done to Augustus Caesar. In both of these cases one day was taken from February and added to the re-named month so that the honour might be more conspicuous. This juggling of days made a still further juggling necessary in an effort to make the quarter-years and half-years of uniform length. All these unnecessary changes are present in the calendar now in use.

By means of specially prepared calendars the speaker showed the appearance of the proposed new calendars. These included the Thirteen Month Plan, the World Calendar Plan of twelve months made up of four equal quarters, and a somewhat similar plan recently proposed by Mr.

Parmalee of Chicago. The relative merits of these plans were discussed in detail, together with the claims which have been made by the supporters of each plan.

The speaker than read extracts from reports on the October (1931) meeting of the committee of the League of Nations which is charged with bringing in recommendations on calendar reform. From these it was apparent that there is a wide diversity of opinion as to the best solution of the problem of reforming the calendar. Incidentally the Canadian delegate to the committee was authorized to vote in favour of the Thirteen Month Plan. There appears to be a decided opinion against the Thirteen Month Plan in England. The English delegate went so far as to say that any decided move in the direction of the Thirteen Month Plan would have the result of alienating British public opinion from favourable consideration of any plan for calendar reform. Apparently the high regard in which Britain is held within the League went far in influencing the actions of the delegates. It was largely on account of the conservative British attitude that slight progress was made in the committee discussions. The final outcome was a resolution that the various countries endeavour to agree on a satisfactory date upon which to permanently fix Easter Sunday. This matter, together with any developments on the reformation of the calendar, are to be discussed at the next meeting, which is to be held in May, 1933.

It is to be noted that a determined attack on the Thirteen Month Plan was made by some of the League Committee delegates. This resulted in a suggestion by the promoters of the Thirteen Month Plan that the perpetual feature of the plan be dropped (that is to say, the blank day at the end of the year should not form a part of their plan). This was an effort to placate those delegates who on account of religious reasons object to any scheme which will interfere with the regular succession of the days of the week as they now stand, which succession would be disrupted by any change making use of a blank day. This giving of ground was held by the speaker to be an evidence of weakening on the part of those sponsoring the Thirteen Month idea, and probably presaging the ultimate abandonment of the scheme in favour of the proposal for twelve months which form equal quarters. In his opinion it was doubtful that anything definite could be looked for before 1939. The only possible way in which any results could ever be obtained was to give the whole matter the utmost publicity in order that the public should become fully acquainted with the different plans and so form their own opinions. This should result in a demand for change that would be an authorization to legislators to go ahead and put any sound idea into effect. Nothing in the way of interest can be expected from a people who are not even aware of the most obvious defects in the calendars which they now use.

President McKone thanked Major Anundson for his instructive address. The members then adjourned to the roof, for outside observations under the direction of Mr. T. C. Benson.

February 12.—A regular meeting of the London Centre was held at 8 p.m., in the London Life Building. There were forty members present, with one election to membership, viz., Mrs. A. E. Hutchinson, 16 Marley Place, London.

President McKone called on Dr. H. R. Kingston to introduce the guest-speaker of the evening, Mr. R. A. Gray, of Toronto. The subject of Mr. Gray's address was "How to Measure the Distances of Stars." The speaker defined the two units of stellar distance, namely, the light-year (approximately six millions of millions of miles) and the parsec, which is equal to 3.26 light-years. The parallax of a star is defined to be the angle subtended at the star by the semi-diameter of the earth's orbit. Hence a star's parallax may be obtained by solving a triangle with one vertex at the star under consideration and the opposite side equal to the radius of the earth's orbit. By definition a star at a distance of 1 parsec has a parallax of 1″. Since parallax varies inversely as the distance, the distance of any star whose parallax is p″, is $3.26/p$ light-years. The nearest star is so remote that its parallax is 0″.75; hence its distance is 4.3 light-years. The smallest parallax that can be measured is about 0″.005, corresponding to a distance of 650 light-years, which, accordingly, represents an upper limit to the distance which can be obtained by the trigonometric method. The distances of perhaps 3,000 stars have been obtained in this manner. The trigonometric method is limited by the smallness of the base of the triangle which is to be solved. Professor de Sitter has pointed out that this limitation could be removed by using as a base line the distance which the sun travels during a long period of time, say a century.

A second method of measuring star distances is given by the period-luminosity relation in Cepheid variable stars. The absolute magnitude of a star is defined as the apparent (visual) magnitude which the star would have if removed to a distance of 10 parsecs. The speaker pointed out that if M and m represent respectively the absolute magnitude and apparent magnitude of a star, and if p represents the star's parallax measured in seconds, then

$$M - m = 5\ (1 + \log p)$$

In 1908 Miss Leavitt of Harvard Observatory discovered that the period of a Cepheid variable varies directly as the apparent brightness of the star. This fact leads to a correlation between the absolute magnitude and the period of a Cepheid. The period can be determined by observation and the apparent magnitude by comparison. Hence M and therefore p can be obtained for any Cepheid variable. The distance in light-years is then given by the expression $3.26/p$. The speaker showed that the trigonometric method of obtaining parallax and the method of the period-luminosity relation give very close results in the cases of those near Cepheids for which both methods are applicable.

A vote of thanks to Mr. Gray was proposed by Rev. R. J. Bowen, seconded by Rev. W. G. Colgrove, and unanimously adopted. A constellation

study was then conducted by Dr. H. R. Kingston, after which the meeting adjourned to the roof of the building for outside observations.

G. R. MAGEE, *Secretary-Treasurer.*

AT TORONTO

January 12.—A regular meeting was held at 8.00 p.m., in the Physics building of the University of Toronto; Mr. R. A. Gray in the chair.

Mr. J. R. Collins requested that members who have any suggestions regarding the total eclipse of the sun to be visible in the province of Quebec on August 31 next should communicate with the committee recently appointed by the general Council to make plans in connection with observing the eclipse.

The paper for the evening was presented by W. E. W. Jackson, M.A., assistant director of the Meterological Service of Canada, whose subject was "New and Old Methods of Determining the Earth's Magnetic Field." Mr. Jackson traced the history and use of the magnetic compass from about 5000 B.C., when the ancient Chinese knew of a metallic ore, now called lodestone, of which two pieces would attract one another and stick together, or, if floating freely, would persist in taking up a definite orientation. No further advances of great importance were made in the study of magnetism until about the time of Columbus, when it was noticed that the magnetic compass did not direct itself to true north. At a later date it was found that the angle of declination from the true geographical north varied at any particular station, and the motion of the magnetic poles was observed. Mr. Jackson described the various methods used in studying the earth's magnetic field, and particularly stressed the electrical methods which were first used about 1890. He stated that it was very difficult to construct a dip-needle which would accurately determine the angle of inclination, and that the earth-inductor coil method could measure the magnetic inclination with much greater accuracy than the dip-needle.

February 9.—The regular meeting was held in the usual place at 8 p.m.; Mr. R. A. Gray in the chair.

Five persons were elected to membership:—

W. B. Watson, 26 Vesta Drive, Toronto
Leslie H. Turl, 16 Gough Avenue, Toronto
James C. Koehl, 671 East 42nd St., Los Angeles, Cal.
L. R. Schulet, 1907 S. 3rd Ave., Maywood, Ill., U.S.A.
Alan Gee, Fort Humphreys, Virginia, U.S.A.

Mr. J. R. Collins reported a recent meeting of the Eclipse Committee, at which it was decided to arrange two or three parties of members from all the centres of the Society. These parties should, if possible, include all members of the Society who were going to Quebec province to view the eclipse, and who would not be attached to one of the government or

university expeditions. The groups should take different stations along the central line. Mr. Collins hoped that recording apparatus might be procured, and that funds might be forthcoming from the government to cover the expense of transporting telescopes and other instruments. He thought that those members who are gifted with the ability to sketch or paint, might draw diagrams of the corona and prominences at the total phase.

The paper for the evening was given by Professor J. Chapelon, D.Sc., formerly of Paris, France, and now on the staff of the department of mathematics of the University of Toronto. Dr. Chapelon's topic was "Newton and Laplace."

Professor Chapelon traced Newton's life from his birth in 1642, through Trinity College, Cambridge, which he entered in 1661, his election as a Fellow of Trinity College in 1667, his career as professor, his election to the Royal Society in 1672, the publication of his "Principia" in 1687, his political career and sudden rise from poverty to great fortune as Member of Parliament for Cambridge University under William of Orange, and his later appointment to the position of Master of the Royal Mint.

In 1700 Newton discovered the sextant, and described it in a letter to Halley, his life-long friend. He was elected to the Presidency of the Royal Society in 1703, and was knighted in 1709.

While at Cambridge, Newton on one occasion sent his resignation to the Royal Society, as on account of extreme poverty he could not afford the weekly fee of one shilling. His resignation was not accepted, and he was exempted from payment of the regular subscription. He died in 1729, President of the Royal Society, and a very wealthy man, the result of whose discoveries in the fields of physics and mathematics was to make present day man more different from his antecedents of the 17th century, than they were from their paleolithic ancestors.

Laplace lived almost a century after Newton, having been born in Normandy in 1749. After many years in Paris as a scholar and instructor of natural philosophy and mathematics, he, too, entered the political world, first as French cabinet minister, later as senator, and in 1803 he became Chancellor of the Senate. His greatest achievements were in mathematical astronomy and the study of the system of the Universe. Laplace died in 1829, one hundred years after Newton, almost to a day.

The thanks and appreciation of the audience were tendered to Professor Chapelon by Dr. R. K. Young, president of the Society.

February 23.—A regular meeting was held at 8.00 p.m., Tuesday, February 23, 1932, in the McLennan Laboratory, (formerly Physics Building,) University of Toronto.

In the absence of the chairman of the Toronto Centre, Mr. A. R. Hassard, vice-chairman, presided.

Six persons, nominated at the previous meeting, were duly elected to membership in the Society:—

Mr. Yasuaki Iba, Astronomical Observatory, Ohte, Kobe, Japan
Stephen G. Talman, 88 Delaware Avenue, Toronto
F. L. Harvey, 80 Gates Avenue, Toronto
Thomas N. Smith, 248 Sumach Street, Toronto
S. Nicholson, 114 Jackman Avenue, Toronto
Alex. Russell, 159 College Street, Toronto

The assistant librarian reported accession of periodicals to the library since January 1, 1932, as follows:—

From Canada and the British Empire	20	
From the United States	28	
From other countries	12	Total 60

The astronomical phenomena for the next two weeks were outlined by F. L. Troyer. Mr. Hassard reported a somewhat peculiar symmetrical beam of bright light extending vertically some ten or twelve degrees from the sun at the time of sunrise on February 19. This phenomenon was observed from Caledon mountain, and short rainbow arcs were visible for some time at a distance on each side of the sun.

J. H. Horning, M.A., then addressed the audience on the subject of "Measuring Stellar Diameters," describing the three methods by which the linear diameters of celestial bodies are determined. The first astronomical diameter measured with any degree of certainty was that of the earth. This determination was made by Eratosthenes, a Greek astronomer, who, from simultaneously observing the difference in the sun's altitude at Alexandria and Syene, and measuring the distance between these stations, was able to calculate the length of one degree of latitude, and thus the circumference and radius of the earth. A similar result can be found by measuring the change in altitude of a given fixed star at different latitudes.

In the case of objects which show a disc, such as the sun, moon, planets and their satellites, the angular diameter may be readily measured with a micrometer attached to the telescope, and if the distance is known, the linear diameter is easily found by trigonometrical or geometrical methods. The distance is found by a method similar to that used by surveyors in determining the distance of an inaccessible object, using in the case of the moon and planets, the distance between two observatories on the earth as the base line, and, where longer distances are to be measured, the diameter of the earth's orbit, observations being made from the same observatory, but six months apart.

Until recently such methods failed when applied to stars, and an indirect method was found by which stellar diameters were calculated. This method is based on three observations, (1) the star's distance, (2) its luminosity, and (3) the surface temperature. The magnitude is measured by photometric means and the absolute magnitude or actual luminosity found by comparing the apparent magnitude and the distance. A study of the star's colour and spectrum reveals its surface temperature. The total amount of energy

radiated is known. The energy radiated per square unit of surface is determined from the temperature. Then by mensuration the total surface area, and hence the diameter, is measured.

The third method described is that of measuring the angular diameter with the interferometer and the distance by parallax. The interferometer method, devised by Michelson at the University of Chicago in 1891 and first successfully used in stellar work in 1920, depends on the interference of light waves. If the objective lens of the telescope is covered with a plate with two narrow parallel slits, the effect is a series of bright and dark bands on the spurious disc image of the star. The dark bands are caused by the interference of light from one slit with the light from the other; the bright bands appearing where light waves in the same phase coincide. This interference was illustrated by an experiment with tuning-forks of slightly different frequency being sounded simultaneously, producing "beats."

In using the interferometer with stars which have a sensible diameter, each half of the star's surface may be considered separately from the other half, and the slits are separated until each half of the surface produces its own image and its own interference bands. By continuing the separation of the slits, the dark fringes of one image finally coincide with the bright fringes of the other image, and no bands are visible. When this condition is secured the angular diameter of the star may be calculated from the relation,

$$\text{angular diameter} = ''1.22\,\frac{\text{wave length of star's light}}{\text{distance between slits}}$$

A comparison of the results obtained by calculation (using the distance, luminosity and temperature), and by the interferometer method, shows a close agreement, the one method giving support to the other.

FRED L. TROVER, *Acting-Recorder.*

AT OTTAWA

December 17, 1931.—On this date the last public meeting for the calendar year was held in the Victoria Memorial Museum. Mr. J. S. Lane, the president, was in the chair.

The chairman introduced Mr. R. Glenn Madill, of the Dominion Observatory, who spoke on the "Art of Pathfinding." Mr. Madill showed many interesting slides taken by himself on his extensive travels throughout northern Canada in the interests of the magnetic survey carried on by the Dominion Observatory.

The lecturer spoke in part as follows:—"Pathfinding is an art acquired only by experience. It is an art needed more in areas of northern Canada that have not as yet been well mapped, and so is not required except by those whose work necessitates travel along the canoe routes in remote sections of the Northland.

To an expert canoeman, travel by rivers and lakes in well mapped areas

is a simple undertaking. The latest maps of many sections of northern Canada give detailed information regarding rapids and falls and thereby convey warnings of danger that can be avoided. But when maps are either poor or lacking, problems of a different nature must be faced and solved.

To locate the beginning of the portages around rapids and falls, to find the place where one must leave a certain river system to cross the height of land to another, to find where a river leaves a lake, and to travel day after day without losing one's way in a country where delays are dangerous—these are some of the problems that are solved by means of observation and deduction.

Along unfamiliar trails every artificial sign has a meaning. A lob-stick usually denotes a portage or a standard camping place. Knotted reeds in a marshy lake indicate a channel to the incoming or outgoing creek, and the flight of ducks often gives the direction in which to look for a river where it leaves a lake, especially where a maze of bays tend to deceive the traveller.

The most valuable aid to navigation in the north is the current, which can usually be detected in the lakes as well as in the rivers. This aid is most invaluable on rivers such as the Churchill, which is mainly a series of lake expansions. The current carries sediment in suspension that gives to the water a milky hue, whereas stagnant water is clear, and small tributary rivers and creeks contain water of a brownish colour. So long as one remains on the milky water there is no danger of straying from the proper route. In lakes the current can be detected by observing the underwater vegetation in narrows between islands. In these situations the weeds will point in the direction in which the current flows.

Often by climbing an elevation the route ahead may be readily seen, and in case it cannot, as happens on lakes, the procedure is to travel towards the lowest part of the horizon.

With a few seasons' experience, an expert canoeman will have no difficulty in finding his way in any part of northern Canada, a proof of which lies in the fact that officials of the Dominion Government whose work takes them along the byways of the north almost invariably return to civilization when their season's work is completed."

At the close of the lecture, the president thanked Mr. Madill, on behalf of the society, for his address.

January 15, 1932.—The fourth regular meeting of the season was held in the Victoria Memorial Museum. The president, Mr. J. S. Lane, was in the chair.

Mr. Lane introduced the speaker of the evening, Professor A. H. S. Gillson, M.A. (Cantab.), of McGill University. Mr. Gillson's subject was "The Nebulae," and he treated the subject in a most interesting manner, starting from the time of the first telescopic observations and tracing the development up till the present. In concluding, he made some references to

the ideas of the expanding universe, and the hypotheses of Einstein, de Sitter and Lemaitre.

As this lecture was delivered to the Montreal Centre last year, a fuller account of it may be found on page 275 of the JOURNAL for 1931.

At the close of the meeting the president announced that the Council had decided to hold a series of informal technical lectures this winter for members of the Ottawa Centre. These meetings will be held in the Dominion Observatory, and will include:—Director R. Meldrum Stewart, on Theory of Errors. A. H. Miller, on The Theory and Operation of the Eotvos Torsion Balance. W. W. Doxsee, on Decoding Seismograms. J. P. Henderson, on Operating Characteristics in Radio Tubes.

MIRIAM S. BURLAND, *Secretary.*

AT VANCOUVER

December 8, 1931.—The second regular meeting was held with Dr. G. M. Shrum in the chair.

The meeting was devoted to an exhibition and discussion of telescopes and telescope making for amateurs. Mr. H. C. Forsyth introduced the discussion with a brief address on the history of the development of the telescope from the time of Galileo to the great instruments of the present day.

Mr. Forsyth's address was followed by an exhibition of telescopes owned by amateur astronomers in Vancouver. Four completed instruments of sufficient power for much interesting visual observation were shown, and also several instruments in course of construction.

Mr. J. Teasdale gave an account of the method of the finishing and testing of mirrors for small telescopes, with some figures on the exactitude with which the parabolic figure must be attained in order to give good definition.

Mr. J. L. Bennett and Mr. Mackenzie gave a demonstration of the Foucault knife edge test for the perfection of the figure.

January 12, 1932.—The third regular meeting was held with Dr. G. M. Shrum in the chair.

Dr. H. Grayson Smith of the University of British Columbia gave an address on the "Nature of a Star." He outlined first the data available for the study of the internal conditions of individual stars, discussing the diameters, masses, temperatures and densities of various stars for which these quantities are known. He then dealt in popular language with the conceptions of Eddington and others concerning the internal constitution of the stars, and of the state of matter under stellar conditions.

February 9.—The fourth regular meeting was held with Dr. G. M.

Shrum in the chair. Dr. J. A. Pearce of the Dominion Astrophysical Observatory, Victoria, gave the address for the evening. Before commencing his address he conveyed the congratulations and good wishes of the Victoria Centre on the formation of the new centre. He then outlined for the benefit of the many new members the history of the Society. He also showed the possibilities which are open to owners of telescopes of moderate power to make valuable observations on variable stars, and told of the American Association of Variable Star Observers.

Dr. Pearce chose as the subject for his address the "Rotation of the Galaxy." In it he showed first how the conception of the galaxy has been gradually extended in the course of time, and how the position of the solar system has been moved farther from the centre until to-day we arrive at the modern conception of Shapley and others, with the galaxy as a great spiral nebula, one among many others of a similar nature, with a diameter 200,000 light-years, and the sun far removed from its centre. He then described in some detail the method which has been used by himself and Dr. J. S. Plaskett in order to prove that the galaxy is in rotation around its distant centre by considering the differences in the radial velocities of moderately distant stars in different quadrants of the galactic plane.

H. Grayson Smith, *Secretary*.

AT MONTREAL

April 30, 1931.—The fifth meeting for the season 1930-31 was held at the Macdonald Physics Laboratory. The president, Dr. L. V. King, took the chair. He introduced the lecturer, Professor H. H. Plaskett (formerly of Victoria, B.C.), now of Harvard College Observatory, the subject being "Stellar Spectroscopy."

Professor Plaskett discussed his subject under four headings: (1) Intrinsic physical properties, (2) Distribution of stars, (3) The sun as a typical star, (4) Abnormal stars.

The second topic led to a discussion of the stars within thirty-two light years of the sun, (105 stars), the luminosities and correlations with spectral class and mass, involving the work of Dyson, Eddington, Hertzsprung and Luyten. The third section led to the lecturer's own field of research—the explanation of the sharp limb and the darkened edge of the sun. The surface temperature was given at 5740°K.

In conclusion the recent investigations and speculations regarding the elliptical nebulae were outlined—the assymetrical brightness giving rise to the density value of 10^{-20} and the hypothesis that these are each a giant star of mass 10^{7} rather than an aggregation of stars and gaseous matter.

The thanks of the Society were expressed by Dr. A. S. Eve and Dr. C. W. Hendel.

A. Vibert Douglas, *Secretary*.

The Royal Astronomical Society of Canada

OFFICERS FOR 1932

Honorary President—R. M. STEWART, M.A., F.R.S.C., Ottawa.
President—R. K. YOUNG, Ph.D., Toronto.
First Vice-President—MGR. C. P. CHOQUETTE, M.A., Lic.Scs., Montreal.
Second Vice-President—LACHLAN GILCHRIST, M.A., Ph.D., Toronto.
General Secretary—R. A. GRAY, B.A., 198 College St., Toronto.
General Treasurer—J. H. HORNING, M.A., 198 College St., Toronto.
Recorder—E. J. A. KENNEDY, Toronto. *Librarian*—R. A. GRAY, B.A., Toronto.
Curator—ROBERT S. DUNCAN, Toronto.
Council—D. S. AINSLIE, M.A., Ph.D., Toronto, Ont.; NAPIER DENISON, Victoria, B.C.; MISS A. VIBERT DOUGLAS, Ph.D., Montreal; R. E. DELURY, M.A., Ph.D., Ottawa; E. A. HODGSON, M.A., Ottawa; A. R. HASSARD, K.C., Toronto; J. A. PEARCE, M.A., Victoria; J. PATTERSON, M.A., Toronto; JOHN SATTERLY, M.A., D.Sc., Toronto; L. A. H. WARREN, M.A., Ph.D., Winnipeg; and Past Presidents—SIR FREDERIC STUPART; C. A. CHANT, M.A., Ph.D.; A. T. DELURY, M.A.; L. B. STEWART, D.T.S.; J. S. PLASKETT, D.Sc., F.R.S.; A. F. MILLER; J. R. COLLINS; W. E. W. JACKSON, M.A.; R. MELDRUM STEWART, M.A.; A. F. HUNTER, M.A.; W. E. Harper, M.A.; H. R. KINGSTON, M.A., Ph.D., and the Presiding Officer of each Centre as follows—J. S. Lane, B.A., Ottawa; DR. L. V. KING, Montreal; N. J. MACLEAN, M.D., Winnipeg; P. H. HUGHES, Victoria, B.C.; E. H. MCKONE, London, Ont.; W. S. MALLORY, M.A., Hamilton; G. M. SHRUM, Ph.D., Vancouver.

TORONTO CENTRE

Honorary President—SIR FREDERIC STUPART. *Chairman*—R. A. GRAY, B.A.
Vice-Chairman—A. R. HASSARD, B.C.L. *Secretary*—E. J. A. KENNEDY
Treasurer—DR. W. M. WUNDER *Recorder*—S. C. BROWN
Curator—F. L. TROYER
Observation Committee—DR. C. A. CHANT, J. R. COLLINS, A. R. HASSARD, A. F. HUNTER, DR. D. B. MARSH.

OTTAWA CENTRE

Hon. President—C. C. SMITH, B.A., D.L.S. *President*—J. S. LANE, B.A.
Vice-President—R. GLENN MADILL
Secretary—MISS M. S. BURLAND, B.A., Dominion Observatory, Ottawa
Treasurer—A. W. GRANT, B.A.
Council—A. H. MILLER; J. P. HENDERSON; N. A. IRWIN, B.A.; and Past Presidents—R. M. STEWART, M.A.; R. E. DELURY, M.A., Ph.D.; R. J. MCDIARMID, M.Sc., Ph.D.; C. R. COUTLEE, C.E.

MONTREAL CENTRE

Honorary President—MGR. C. P. CHOQUETTE *President*—DR. L. V. KING
First Vice-President—G. HARPER HALL, *Second Vice-President*—DR. JULIAN C. SMITH
Secretary-Treasurer—DR. A. VIBERT DOUGLAS, McGill University
Council—DR. A. S. EVE; LT.-COL. W. E. LYMAN; JUSTICE E. E. HOWARD; H. E. S. ASBURY; DR. BELL DAWSON; MISS THIBAUDEAU; DR. F. R. ENGLAND; DR. C. C. BIRCHARD; DR. A. H. MACCORDICK; PROF. N. B. MCLEAN.

LONDON CENTRE

Hon. President—H. R. KINGSTON, M.A., Ph.D., F.R.A.S.
President—E. H. MCKONE, B.Paed. *Vice-President*—T. C. BENSON
Secretary-Treasurer—G. R. MAGEE, B.A., S.M., 427 William St.
Council—F. H. COATES, A. CALLARD, F. W. DALY, F. FISHER, G. A. MINHINNICK.

WINNIPEG CENTRE

President—N. J. MACLEAN, M.D. *Vice-President*—A. W. MEGGET
Treasurer—J. H. KOLB *Secretary*—MRS. J. NORRIS, 569 Sherburn St.
Council—D. R. P. COATS; RT. REV. T. W. MORTON; MRS. E. L. TAYLOR; J. HOUSTON; PROF. K. W. JACKSON; R. MACCALMAN; DR. L. A. H. WARREN.

VICTORIA CENTRE

Honorary President—J. A. PEARCE, M.A., Ph.D. *President*—P. H. HUGHES
First Vice-President—N. C. STEWART *Second Vice-President*—CAPT. J. N. HUGHES
Secretary-Treasurer—H. BOYD BRYDON, 2390 Oak Bay Avenue, Victoria, B.C.
Council—J. P. HIBBEN; JOHN DEAN; REV. J. GOODFELLOW; CHAS. HARTLEY; DR. FRANK HOGG.

HAMILTON CENTRE

Hon. President—REV. DR. D. B. MARSH, Norwich, Ont.; *President*—W. S. MALLORY, M.A.;
Vice-Presidents—REV. JOHN SAMUEL, T. H. WINGHAM, PROF. W. FINDLAY, Ph.D.
Secretary-Treasurer—GEO. E. CAMPBELL, 142 Gladstone Avenue.
Curator—HUGH RODGER; *Council*—DR. GORDON M. JACKSON, MISS W. PARKER, W. T. GODDARD, DR. W. R. JAFFRAY, W. G. MILNE, W. HODGSON, J. A. LITTLE, S. C. SCAMMELL, MISS A. B. MARSH.

VANCOUVER CENTRE

Hon. President—DEAN D. BUCHANAN. *President*—G. M. SHRUM, M.A., Ph.D.
Vice-President—STANLEY BURKE. *Recorder*—H. GRAYSON SMITH, M.A., Ph.D.
Treasurer—J. L. BENNETT.
Council—MRS. M. A. KELK, MRS. C. M. ROBSON, F. R. WILLIAMS, T. J. MCGILL, J. A. MACKENZIE, H. A. PITMAN, A. OUTRAM.

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The Astronomical and Physical Society of Toronto was incorporated in 1890, though it had existed some years before this; in 1900 it became The Toronto Astronomical Society; and on March 3, 1903, it was given permission to use the name, The Royal Astronomical Society of Canada.

Its objects are to study astronomy and cognate subjects, to publish the results of its work, and to maintain a library.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton and London, Ont.; Winnipeg, Man.; Victoria and Vancouver, B.C. Among its 800 members are a number of leading astronomers and scientists of the world, many amateurs, and, in addition, many laymen who are interested in the culture of the science.

The Society publishes a monthly JOURNAL containing each year about 500 pages of interesting articles and a yearly OBSERVER'S HANDBOOK of about 80 pages, containing valuable information for the amateur observer. Single copies of the JOURNAL or HANDBOOK are 25 cents.

Membership in the Society is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00 (no further dues). Publications are free to the members, or may be subscribed for separately.

Extract from the By-Laws: Candidates who are elected to membership will be attached to a particular Centre, or to a section known as *Members at Large*. Members of the Society who live outside of Canada, or in a province in which there is no Centre of the Society will be considered *Members at Large* and not attached to any particular Centre, unless these members are expressly nominated for membership and attachment to a particular Centre. Members may be transferred from one Centre to another, or to the section *Members at Large* by the Council of the Society if written application for such transfer is made by such member to the Council.

The library and offices of the Society are at 198 College St., Toronto, Ont. Applications for membership or for further information should be addressed to a local secretary (see back of this page) or to the General Secretary at the above address.